

REPORT DOCUMENTATION PAGEForm Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Service, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) 05-11-2003			2. REPORT DATE FINAL REPORT		3. DATES COVERED (From - To) From 01-05-1999 to 30-09-2003	
4. TITLE AND SUBTITLE Bioacoustic characterization of the Mediterranean Sea					5a. CONTRACT NUMBER ONR Grant N00014-99-1-0709	
					5b. GRANT NUMBER ONR Grant N00014-99-1-0709	
					5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) PAVAN, Gianni					5d. PROJECT NUMBER 20031114 009	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Centro Interdisciplinare di Bioacustica e Ricerche Ambientali Università degli Studi di Pavia Via Taramelli 24 - 27100 Pavia - ITALY					8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research 800 North Quincy Street Arlington, VA 22217-5000 USA					10. SPONSOR/MONITOR'S ACRONYM(S) ONR	
					11. SPONSORING/MONITORING AGENCY REPORT NUMBER	
12. DISTRIBUTION AVAILABILITY STATEMENT Distribution Unlimited						
13. SUPPLEMENTARY NOTES Research program carried in cooperation with Saclancen, La Spezia, Italy						
14. ABSTRACT Aerial and ship-based surveys were carried out to provide baseline information about marine mammal presence, distribution and acoustic behaviour in the Ligurian Sea (Cetacean Sanctuary). Combined acoustic and visual surveys were mainly carried out during the SIRENA cruises organized by Saclancen within the SOLMAR Project. Acoustic monitoring with towed arrays was performed 24h/day to investigate the diel acoustic patterns. For these purposes, a lightweight wideband towed array and a complete asset for signal recording and analysis, providing high-resolution wide-band processing capabilities, were developed. Databases (strandings, sightings, acoustic contacts, literature) were developed by examining the literature, by collecting data from different organizations, and by conducting field research.						
15. SUBJECT TERMS Underwater bioacoustics, marine mammals, acoustic signatures, Mediterranean Sea						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT	b. ABSTRACT	c. THIS PAGE	UP	4	Pavan, Gianni	
Unclass.	Unclass.	Unclass.			19b. TELEPHONE NUMBER (include area code) +39-0382-507874 gpavan@cibra.unipv.it	

FINAL REPORT

GRANT #: N00014-99-1-0709

PRINCIPAL INVESTIGATOR: Dr Gianni Pavan

INSTITUTION: Centro Interdisciplinare di Bioacustica e Ricerche
Ambientali dell'Università di Pavia, Italia

GRANT TITLE: Bioacoustic characterization of the Mediterranean Sea

AWARD PERIOD: 1 May 1999 - 30 September 2001

OBJECTIVE:

The long term goal of the project is to create a comprehensive database on marine mammals and ecosystem dynamics in the Mediterranean Sea and to develop the equipment for conservation strategies support, acoustic impact evaluation and Acoustic Risk Mitigation Policies implementation. The research is within the scope of the Saclantcen's Joint Research Project named Sound, Oceanography and Living Marine Resources (SOLMAR), which is an interdisciplinary program headed by NATO Saclantcen (Italy) that addresses the issue of underwater noise and its effects on the marine environment.

APPROACH:

The on-field part of the project included the collection of information on acoustic and visible behaviour of cetaceans as well as on the biological-oceanographical parameters that year-around characterize the environments they live in. Aerial and ship-based surveys were carried out to provide baseline information about marine mammal presence, distribution and acoustic behaviour in the Ligurian Sea (Cetacean Sanctuary).

To collect information on ambient noise and cetaceans acoustic behaviour, stationary hydrophones, towed arrays and radio-linked sonobuoys were used for acoustic monitoring. Combined acoustic and visual surveys were carried out on chartered or opportunistic motorsailing boats and during the SIRENA cruises organized by Saclantcen within the SOLMAR Project. In SIRENA cruises acoustic monitoring with towed arrays was performed 24h/day to investigate the diel acoustic patterns.

Databases were developed by examining the literature, by collecting data from different organizations, and by conducting field research.

ACCOMPLISHMENTS:

Surveys

Participation to SIRENA 99, 00 and 01 cruises; organization of aerial surveys with helicopters (1999) and ASW airplanes (2000) with the support of the IT Navy; opportunistic research cruises were organized with motorsailers for equipment testing and data collection. Support to the WHOI tagging project was extensively provided during Sirena cruises.

Databases

The project included the development of a set of databases (strandings,

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

sightings and acoustic contacts) to support the development of models for predicting the presence of marine mammals according to season and environmental parameters. Databases are included into the SOLMAR Database kept at Saclantcen.

The Digital Sound Library kept at CIBRA includes the entire set of omnidirectional acoustic recordings resulting from the project (beamformer data are kept at Saclantcen).

Equipment

A PC based Digital Signal Processing Workstation (DSPW) was developed to meet specific sound recording and analysis requirements needed for this project. The DSPW runs in a standard Microsoft Windows environment and can use a variety of off-the-shelf signal acquisition devices. Depending on the acquisition devices, recording, analysis and display can be performed in real-time up to 800 ksamples/sec to provide useful bandwidth to more than 300 kHz. The software was primarily developed for continuous real-time monitoring in bioacoustical studies. It offers from 2 to 8 channels sound recording with high-resolution real-time spectrographic display. While displaying spectral characteristics of the signals, the software can continuously record to a disk array, in standard format and pre-determined time-cuts. A specific data logging software was developed to allow easy logging of predetermined acoustic categories observed by operators with 1 minute time resolution. Additional features developed within the project allow to log events and GPS data, to georeference acoustic files, and to produce a GIS-ready data set.

To integrate the sensors available on the RV Alliance, a lightweight wideband towed array of hydrophones was designed and assembled at CIBRA. In the first version it was made with four acceleration-compensated sensors (Benthos AQ4 - flat frequency response up to 16 kHz), one wideband sensor (Cetacean Research Technology C300 - freq. response up to 300 kHz) and two pressure transmitters.

During Sirena 01 it was towed together with the Saclantcen 128 hydrophone array. The two arrays were towed at different depths to monitor sounds below and above the thermocline. Stationary hydrophones with more than 200 kHz bandwidth were also used to record echolocating dolphins.

CONCLUSIONS:

As proved by "Dual Use" trials in Sirena 99, an acoustic detection equipment with "wider-than-usual" band was needed, together with new instruments suited for the specific needs of bioacoustic research. This led to the development of a lightweight wideband towed array and of a complete asset for signal recording and analysis, providing high-resolution wide-band processing capabilities.

In the following SIRENA cruises, the use of new equipment allowed to gather wide-band recordings (24 kHz, 48 kHz, and 160 kHz bw) of the most common species of the Mediterranean Sea. Continuous acoustic monitoring with at least 24 kHz bandwidth, with both simple towed arrays and the 128 elements beamforming array, proved to be an excellent method to detect the marine mammals' presence in a given area.

The continuous high-resolution display of received underwater signals, even short and weak ultrasonic signatures, can show the presence of both near and distant dolphins or whales. Zooming into the low frequency range it is also possible to highlight fin whale sounds. Often, acoustic detection largely anticipated, in the daylight, visual sightings, while

1.

during night-time surveys it allowed the detection of not visible animals and behaviours. Depending on the equipment, the observation platform and most of all on personnel skills, the comparison between results gained with passive acoustics and visual sightings is still a matter of discussion. It is evident that the two methods should be improved and integrated to provide accurate results while studying marine mammals and their environment.

The acoustic system was tested as a monitoring tool for the implementation of mitigation policies aimed at reducing the impact, on marine mammals, of underwater high power acoustic sources. Connected to suitable sensors, it reveals the presence of vocalizing animals in the operation area and thus warns about a possible threat to marine life.

In Sirena 00 and 01 marine mammals' sounds were detected 40% of the towing time, combining detections from the CIBRA array and omnidirectional sensors in the Saclantcen's array. Additional recordings were made with sonobuoys and stationary hydrophones. The wide area acoustic surveys in the Ligurian Sea allowed gathering 24/24h acoustic recordings (due to storage space constraints 24 kHz bandwidth was used most of the time; samples with 48 and 160 kHz bandwidth were made on specific occasions) for a total of more than 600 hours.

A marked diurnal cycle in the vocalizing activity resulted from the continuous acoustic monitoring. The recordings include a large sample of vocalizations, named "nacchere" (work in progress), received mostly at night in presence of striped dolphins. These signals are currently under examination and characterization. A huge number of sperm whales' vocalizations other than regular clicks were recorded also (trumpets and codas - work in progress).

Other than marine mammal sounds (sperm whales, fin whales, pilot whales, striped dolphins, unidentified dolphins), recordings included many man made sounds with a potential impact on the marine environment: sonar, ship traffic, impulsive noises generated on the coast, etc.

SIGNIFICANCE:

The project supports the US Navy's and ONR's research programs on the effects of underwater noise on marine environment; it is aimed at developing instruments, procedures and skills for detecting cetaceans present in an area and for correlating their presence with local oceanographic features. Results will allow to forecast marine mammals' presence and to monitor responses to anthropogenic disturbance. This complies with the US Navy's project directed by the Environmental Protection, Safety and Occupational Health Division (CNO N45).

The research will contribute to the Mediterranean Sea ecosystem database and will support the development and implementation of Acoustic Risk Mitigation Policies within the SACLANTCEN' SOLMAR Project.

Acoustic signatures of marine mammals collected within the ONR grant, as well as recordings made by CIBRA in previous years, are the core of a Cetacean Digital Sound Library for the Mediterranean Sea. This library provides sound samples to other researchers and institutions. The classification scheme for biological sounds developed by CIBRA is used in the Saclantcen SOLMAR project and has been adopted as a basis for developing automatic acoustic classification software.

PATENT INFORMATION: none

AWARD INFORMATION: none

PUBLICATIONS AND ABSTRACTS:

1. D'Amico A., Fossati C., Portunato N., 1999. Application of graphical digital tools to stranding information mapping of strandings off the Italian coast, 1986-1996. European Research on Cetaceans, 13: 459. Abstract.
2. Fossati C., D'Amico A., Portunato N., Pavan G., Podesta M., 1999. Application of graphical digital tools to stranding information: an open information system for marine mammal studies in the Mediterranean Sea. European Research on Cetaceans, 13: 465-466.
3. Pavan G., 2000. Current research projects. Projets de recherche en cours. Bulletin ACCOBAMS, 3 (December 2000): 32-33
4. Teloni V., Zimmer W.M.X., Fossati C., Manghi M., Pavan G., Priano M., 2000. Variability of temporal and spectral click characteristics of sperm whales (*Physeter macrocephalus*). European Research on Cetaceans, 14: 91-95.
5. Pavan G., Manghi M., Fossati C., 2001. Software and hardware sound analysis tools for field work. Proc. 2nd Symposium on Underwater Bio-sonar and Bioacoustic Systems. Proc. I.O.A., Vol. 23 (part 4): 175-183.
6. Pavan G., 2002. Effects of underwater noise on marine mammals. Les effets des bruits sous-marins sur les mammifères marins. Bulletin ACCOBAMS, 4 (February 2002): 11-14.
7. Pavan G., Manghi M., Fossati C., Priano M., 2002. Low cost tools for sound recording and analysis. Guidelines for a good choice. Bioacoustics 13(2): 205-206. Abstract.
8. Pavan G., Riccobene G., Casentino G., Speziale F., 2002. INFN NEMO Test Platform: an opportunity for a long term study of ocean noise and biological sounds in the Mediterranean Sea. Bioacoustics 13 (2): 184-185. Abstract.
9. Pavan G., 2002. Recording ultrasounds in the field. Bioacoustics 13(2): 206-207. Abstract.
10. Pavan G., Podesta M., D'Amico A., Portunato N., Fossati C., Manghi M., Priano M., Quero M., Teloni V. A GIS and associated database for the Italian Stranding Network. A cooperative project based on GIS technologies. European Research on Cetaceans, 16. In Press.
11. Manghi M., Pavan G., Fossati C., Priano M. - Mapping and analyzing acoustic surveys' results: a GIS approach. European Research on Cetaceans, 16. In Press.

Reports included in

SACLANTCEN CD27 SIRENA 99, CD41 SIRENA 00, CD53 SIRENA 01